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Anvik River Sonar Chum Salmon Escapement Study, 2006

Annual Report for Project 05-208
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Fisheries Information Services Division

by

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Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

The 2006 Anvik River sonar project operated from late June until the end of July to estimate the passage of summer chum salmon *Oncorhynchus keta*. Data from each bank was collected using a Hydroacoustic Technology Incorporated (HTI) split-beam sonar sampling 30 minutes of each hour, 24 hours a day, 7 days a week. The estimated summer chum salmon passage of 605,485 (SE 4,111) was 24% above the minimum escapement objective for the Anvik River Biological Escapement Goal of 400,000 to 800,000 chum salmon. Based on 1979–1985 and 1987–2005 mean quartile passage dates, timing of the 2006 chum salmon run was average. A chum salmon diurnal migration pattern was observed with the highest passage (41%) occurring during the darkest part of the day (2100–0500 hours). Females comprised 50.7% of the catch in beach seines. Age-0.4 fish comprised 58.9% of the chum salmon run in 2006. Side-by-side comparisons of counts obtained with HTI and DIDSON equipment suggest the split-beam estimates were conservative and as many as 992,378 (SE 34,141) fish may have passed the site during the period of operation. We believe the bias in the split-beam estimates was due to high water that prevented normal operations of the counting tower that are used to verify sonar counts inseason.

Key words: chum salmon, *Oncorhynchus keta*, pink salmon, *O. gorbuscha*, sonar, DIDSON, Anvik River

INTRODUCTION

The purpose of the Anvik River sonar project is to monitor escapement of summer chum salmon *Oncorhynchus keta* to the Anvik River drainage, believed to be the largest producer of summer chum salmon in the Yukon River drainage (Bergstrom et al. 1999). Additional major spawning populations of summer chum salmon occur in the following tributaries of the Yukon River: the Andreafsky River, located at river kilometer (rkm) 167; Rodo River (rkm 719); Nulato River (rkm 777); Melozitna River (rkm 938); and Tozitna River (rkm 1,096). Spawning tributaries in the Koyukuk River (rkm 817) drainage are the Gisasa River (rkm 907) and Hogatza River (rkm 1,255); and in tributaries to the Tanana River (rkm 1,118) drainage, which include the Chena River (rkm 1,480) and the Salcha River (rkm 1,553) (Figure 1). Chinook *O. tshawytscha* and pink *O. gorbuscha* salmon spawn in the Anvik River concurrently with summer chum salmon. Fall chum, a later run of chum salmon, and coho salmon *O. kisutch* have been reported to spawn in the Anvik River drainage during the fall.

Timely and accurate reporting of information from the Anvik River sonar project helps Yukon River fishery managers ensure the Anvik River Biological Escapement Goal (BEG) of 400,000 to 800,000 summer chum salmon is met. This assessment is necessary to determine if summer chum salmon abundance will meet upstream harvest and escapement needs.

Side-looking sonar, capable of detecting migrating salmon along the banks, has been in place in the Anvik River since 1980. The Electrodynamics Division of the Bendix Corporation[1] developed the side-looking sonar and conducted a pilot study using the side-looking sonar to estimate chum salmon escapement to the Anvik River in 1979. The results indicated sonar-based estimation of chum salmon escapements to the Anvik River was superior to the counting tower method used at that time (Mauney and Buklis 1980). Bendix sonar equipment was used for escapement estimates from 1979 to 2003. In 2003, a side-by-side comparison was done with Hydroacoustic Technology Incorporated (HTI) sonar equipment where it was found that the Bendix and HTI produced similar abundance estimates (Dunbar and Pfisterer 2007). In 2004, the switch was made to HTI sonar equipment.

[1] Product names used in this report are included for scientific completeness but do not constitute a product endorsement.

BACKGROUND INFORMATION

Commercial and subsistence harvests of Anvik River chum salmon occur throughout the mainstem Yukon River, from the delta to the mouth of the Anvik River and within the first 19 km of the Anvik River. This section of the Yukon River includes Lower Yukon Area Districts 1, 2, and 3, and the lower portion of Subdistrict 4-A in the Upper Yukon Area (Figure 1). Most of the effort and harvest of this stock occurs in Districts 1 and 2, and in the lower portion of Subdistrict 4-A below the confluence of the Anvik and Yukon rivers.

In the Lower Yukon Area, run timing of summer chum and Chinook salmon overlap, with runs beginning at river ice breakup through early July. During this time commercial fisheries in the Lower Yukon Area have traditionally targeted Chinook salmon, while Subdistrict 4-A commercial fisheries have targeted summer chum salmon. In the Lower Yukon Area, large-mesh gillnets (stretch mesh greater than 15.2 cm) were employed to harvest Chinook salmon. Although these nets were efficient for Chinook salmon, the associated harvest of summer chum salmon through 1984 was minor in relation to the size of the chum salmon run. In order to allow directed harvests of summer chum salmon in the Lower Yukon, the Alaska Board of Fisheries (BOF), prior to the 1985 season, adopted regulations allowing fishing periods restricted to small-mesh gillnets (15.2 cm maximum stretch mesh) during the Chinook salmon season provided that (1) the summer chum salmon run was of sufficient size to support additional exploitation, and (2) incidental harvest of Chinook salmon during these small-mesh fishing periods did not adversely affect conservation of that species.

Increased market demand prompted allocation disputes between fishers in different districts. In February of 1990, the BOF established a guideline harvest range of 400,000 to 1,200,000 summer chum salmon for the entire Yukon River, allocated by district and sub-district based on the average harvests of the previous 15 years (ADF&G 1990). Summer chum salmon escapement to the Anvik River exceeded the lower range of the Anvik River BEG (Clark and Sandone 2001) of 400,000 salmon by an average of 233,000 salmon from 1979 to 1993.

In 1994, the BOF adopted the Anvik River chum salmon fishery management plan, which permits a commercial harvest of summer chum salmon in the terminal Anvik River Management Area (ARMA; ADF&G 1994) to allow commercial exploitation of surplus chum salmon returning to the Anvik River. In 1996, the BOF established a harvest limit of 100,000 lbs of chum salmon roe for the ARMA (JTC 1996). A more complete history and background information can be found in Annual Management Reports for the Yukon Area published each year by the Alaska Department of Fish and Game (ADF&G).

OBJECTIVES

The goals for the 2006 Anvik River summer chum salmon study were to estimate the timing and magnitude of adult chum salmon escapement, and characterize age and sex composition. To accomplish these tasks, these specific objectives were identified:

1. Estimate timing and magnitude of chum salmon escapement using fixed-location, split-beam sonar in a side-looking configuration.
2. Estimate age and sex composition of the spawning population with an accuracy of 0.10 and a precision of 0.05 using a beach seine as the capture technique.

3. Monitor selected climatological and hydrological parameters daily at the project site for use as baseline data.

In addition to these primary objectives, a DIDSON sonar was operated side-by-side data with the split-beam sonar in preparation for a transition next season.

METHODS

STUDY AREA

The Anvik River originates at an elevation of 400 m and flows in a southerly direction approximately 200 km to its mouth at rkm 512 of the Yukon River (Figure 1). This narrow runoff stream has a substrate of mainly gravel and cobble. Bedrock is exposed in some of the upper reaches. The Yellow River is a major tributary of the Anvik drainage and is located approximately 100 km upstream from the mouth of the Anvik River (Figure 2). Downstream from the confluence of the Yellow River, the Anvik River changes from a moderate-gradient system to a low-gradient system meandering through a much broader flood plain. Turbid waters from the Yellow River greatly reduce water clarity of the Anvik River below their confluence. Numerous oxbows, old channel cutoffs, and sloughs are found throughout the lower Anvik River.

Anvik River salmon escapements were partially estimated from visual counts made at counting towers above the confluence of the Anvik and Yellow rivers, from 1972 to 1979 (Figure 2). A site 9 km above the Yellow River, on the mainstem Anvik River, was used from 1972 to 1975 (Lebida *Unpublished*; Trasky 1974, 1976; Mauney 1977). From 1976 to 1979, a site on the mainstem Anvik River, near the confluence of Robinhood Creek and the Anvik River, was used (Figure 2; Mauney 1979, 1980; Mauney and Geiger 1977). Since 1979, the Anvik River sonar project has been located approximately 76 km upstream of the confluence of the Anvik and Yukon Rivers, 5 km below Theodore Creek in Sections 34 and 35, Township 31 North, Range 61 West, Seward Meridian, at latitude/longitude 62° 44.208" N 160° 40.724" W (Figure 2). The land is public, managed by the Bureau of Land Management (BLM), and leased to ADF&G for public purposes until 2023. Aerial survey data indicate chum salmon spawn primarily upstream of this sonar site.

SONAR DEPLOYMENT AND OPERATION

Sonar systems operate by transmitting sound waves outward along the riverbed, from transducers located near the shore. Echoes from targets passing through the sonar beam are reflected back to the transducer and processed in the transceiver. Echoes, which satisfy criteria for amplitude and frequency, are considered valid and are counted as fish. Echo selection criteria are designed to estimate fish passage and minimize debris counts. Echoes are combined and the traces counted to estimate fish abundance. For the Anvik River sonar salmon counting project, all fish targets are considered salmon. Paired visual counts from a tower overlooking the sonar confirm that nearly all fish observed are salmon.

An HTI hydroacoustic system was operated at the Anvik River sonar site in 2006. The HTI system consists of an HTI model 241 digital echo sounder (Appendix A1) with a 2° by 10° 200 kHz split-beam transducer on the right bank and a 2.8° by 10° 200 kHz split-beam transducer on the left bank. Attached to the transducers are HTI model 662H dual-axis rotators with an HTI model 660 remote controller to facilitate aiming. The system is capable of distinguishing upstream fish from downstream fish and debris, determining the fish velocity, discriminating between random reverberation and fish targets, and providing a less-biased estimate of target strength than dual or single beam systems (HTI 2000).

The HTI model 241 is a scientific echo sounder designed for fisheries research. Accurate time-varied gain (TVG) stable transmit and receive sensitivities are possible. Short pulse widths can be used to improve resolution between targets. A Digital Echo Processor (DEP) is integrated into the system and paired with a laptop computer to provide access to all the DEP settings. An oscilloscope can be linked to the sounder for diagnostic use, such as in-situ system calibration or transducer aiming. After all parameters are determined for data acquisition, the system operates 24 hours a day sampling each bank alternately for 30 minutes. Files are created by the DEP and edited to produce an estimate of fish passage.

Two HTI sonar systems, one on each riverbank, were operated in 2006. These sites were the same sonar sites used in 2004 and 2005. The right bank transducer was deployed on a slight inside bend, where a gravel bar slopes gently toward the thalweg. The left bank transducer was deployed from a more steeply sloping cut-bank on the outside of the same bend.

The right bank HTI transducer and automatic rotators were mounted on an aluminum mount secured with sandbags. Aim adjustments were made using the remote control for the automatic rotators. The system operator used an artificial acoustic target (1.5-inch tungsten carbide sphere) during deployment to ensure transducer aim was low enough to prevent salmon from passing undetected beneath the acoustic beam. The target was held with monofilament line from a pole along the river bottom and in the acoustic beams at multiple locations to ensure that the full counting range of the transducer was covered. When properly aimed, the target appeared as a trace on the echogram or vertical deflection (spike) on an oscilloscope screen as it transected the acoustic beam at a given distance. The left bank transducer was deployed in similar fashion as the right bank, but with the transducer and rotator cables running under the water to the right bank, where the sounder for both transducers was located in a tent.

SONAR CALIBRATION AND PASSAGE ESTIMATION

At the end of each day, data collected by the DEP in 24 thirty-minute text files for each bank were transferred to another computer for tracking and editing. To facilitate tracking, echoes from stationary objects were removed using a custom program created in *Java* computer language (Dunbar *In prep*). The tracked data were manually edited to remove any spurious tracks such as those from any remaining bottom using *Polaris*, an echogram editor developed by Mr. Peter Withler through a cooperative agreement with the Department of Fisheries and Oceans Canada (DFO), ADF&G, and HTI. The edited data were saved to a *Microsoft Excel* spreadsheet where each 30-minute file representing a sample was multiplied by 2 to account for a full hour. Linear interpolation was used when complete 30-minute periods of data were missing. If data from a complete 30 minutes were missing, counts were interpolated by averaging counts from 2 hours before and 2 hours after the missing period. If two complete 30-minute sample periods were missing, counts were interpolated by averaging counts from 3 hours before and 3 hours after the missing periods. If three 30-minute sample periods were missing, counts were interpolated by averaging counts from 4 hours before and 4 hours after the missing periods. If four or more 30-minute sample periods were missing, counts were interpolated by averaging counts from 5 hours before and 5 hours after the missing the hour. When a portion of a 30-minute sample was missing, passage was estimated by expansion based on the known fraction of the 30 minutes sampled. Thirty minutes was divided by the known number of minutes counted (if 10 minutes or more) and then multiplied by the number of fish counted in that period.

Echoes from stationary objects were removed before tracking by dividing data into range bins (0.2 meters), calculating the moving average (averaging window of 1,000 echoes) of the voltage in each range bin, and then removing the echo if the voltage was within 1.7 standard deviations of the mean and at least 100 echoes were within that range bin. The echo was not removed if the percentage of missed echoes relative to observed echoes was greater than 80. The percentage of missed relative to observed echoes was calculated by summing differences between observed ping numbers minus one and then dividing by the total number of echoes in the range bin.

After the data were cleaned up with the bottom removal program, the echoes were grouped into fish tracks that could be enumerated to produce an estimate of fish passage. Three times a day a technician would manually track fish traces to determine distribution.

Final editing was accomplished with *Polaris*. After all editing was complete, the data were imported to an *Excel* spreadsheet where the final estimate of hourly and daily fish passage was produced. Since the HTI estimates were produced from 30-minute samples, a variance estimate was calculated. Each 30 minute in duration sonar sampling periods, were spaced at regular (systematic) intervals of one hour. Treating the systematically sampled sonar count as a simple random sample would yield an over-estimate, the variance of the total since sonar counts were highly autocorrelated (Wolter 1985). To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations recommended by Brannian (1986) and modified from Wolter (1985) was employed. The daily passage for bank *z* on day *d* was calculated by summing the hourly passage rates for each hour as follows:

$$\hat{y}_{dz} = \sum_{p=1}^{24} \frac{y_{dzp}}{h_{dzp}} \tag{1}$$

where h_{dzp} is the fraction of the hour sampled on day *d*, bank *z*, period *p* and y_{dzp} is the count for period *p* on bank *z* of day *d*.

The variance for the passage estimate for bank *z* on day *d* is estimated as:

$$\hat{V}_{y_{dz}} = 24^2 \frac{1 - f_{dz}}{n_{dz}} \frac{\sum_{p=2}^{n_{dz}} \left(\frac{y_{dzp}}{h_{dzp}} - \frac{y_{dz,p-1}}{h_{dz,p-1}} \right)^2}{2(n_{dz} - 1)} \tag{2}$$

where n_{dz} is the number of samples in the day (24) and f_{dz} is the fraction of the day sampled (12/24=0.5). y_{dzp} is the hourly count for day *d* on bank *z* for sample *p*.

Since the passage estimates are assumed independent between zones and among days, the total variance is estimated as the sum of the variances.

$$\hat{V}ar(\hat{y}) = \sum_{d} \sum_{z} \hat{V}ar(\hat{y}_{dz}) \tag{3}$$

AGE, SEX, AND LENGTH SAMPLING

Temporal strata, used to characterize the age and sex composition of the chum salmon escapement, were defined as quartiles using dates on which 25%, 50%, 75%, and 100% of the total run had passed the sonar site. These quartile-sampling strata were determined postseason based on 2006 run timing data. They represent an attempt to sample the escapement for age, sex, and length (ASL) information in relative proportion to the total run. In 2006, these strata were defined as: Pre July 3, July 4–6, July 7–11, and July 12 until end of the season.

To meet region-wide standards for the sample size needed to describe a salmon population, the initial seasonal ASL sample goal were 608 chum salmon, with a minimum of 162 chum salmon samples collected during each temporal stratum (Bromaghin 1993). Sample size goals are based on accuracy (d) and precision (α) objectives of d = 0.10 and α = 0.05, assuming 2 major age classes, and 2 minor age classes with a scale rejection rate of 15%. The beach seining goal for Chinook salmon was to sample all fish captured while pursuing the chum salmon sampling goal.

A beach seine (31 m long, 66 meshes deep, 6.35-cm mesh) was drifted, beginning approximately 10 m downstream of the sonar site to capture chum salmon to collect ASL data. All resident freshwater fish captured were tallied by species and released. Pink salmon were counted by sex, based on external characteristics, and released. Chum salmon were placed in a holding pen and each was noted for sex, measured to the nearest 5 mm from mideye to tail fork, and 1 scale was taken for age determination. Where possible, scales were removed from an area posterior to the base of the dorsal fin and above the lateral line on the left side of the fish (Clutter and Whitesel 1956). The adipose fin was clipped on each sampled chum salmon to prevent resampling. If any Chinook salmon were caught, they were sampled using the same methods as for chum salmon, except 3 scale samples were taken from each fish.

CLIMATOLOGICAL AND HYDROLOGIC SAMPLING

Climatological and hydrologic data were collected at approximately 1800 hours each day at the sonar site. Relative river depth was monitored using a staff gauge marked in 1 cm increments. Change in water depth was presented as negative or positive increments from the initial reading of 0.0 cm. Water temperature was measured in degrees Celsius (C) near shore at a depth of approximately 50 cm. Daily maximum and minimum air temperatures were recorded in degrees C. Subjective notes on wind speed and direction, cloud cover, and precipitation were recorded.

DIDSON VS SPLIT-BEAM COMPARISON

The Anvik River sonar project will be transitioning to DIDSON and in preparation, a side-by-side comparison between the DIDSON and split-beam systems was performed. Similar work has shown that counts from the DIDSON are typically higher than for single or split-beam sonar (Maxwell and Gove 2004; Sandall and Pfisterer 2006) so it will be important to understand the relationship at this site to allow more direct comparison with the historical estimates.

DIDSON counts were compared to split-beam counts obtained over the same 30-minute sampling periods and compared using standard linear regression with the DIDSON as the independent variable since there were more variability in the split-beam counts. The resulting regression equation was then solved for DIDSON to obtain the conversion equation:

$$DIDSON = \frac{Splitbeam - Intercept}{Slope} \quad (4)$$

High water for most of the season prevented normal operation of the split-beam in 2006 so the side-by-side comparison may not reflect the relationship under normal operating conditions. Although not useful for comparing with historical estimates, it is fortunate the equipment was run side-by-side to allow estimation of what the total run size may have been without high water. The run size was estimated using the regression relationship from each bank and performing a 1000 iteration bootstrap with the hourly split-beam estimates collected over the season. The bootstrap allowed estimation of the standard error for the season total.

RESULTS

ESCAPEMENT ESTIMATES AND RUN TIMING

Full sonar operations on both banks began on June 28. Both transducers collected data through midnight on July 26. The 2006 summer chum salmon passage estimate were 605,485 (SE 4,111) (Table 1). This includes estimates for missing sector/hourly counts and expansions for missing data, for right bank passage on July 1, 2, 11, 17, 18, and left bank passage on July 1, 2, 11, 15-18th. No pink salmon were observed while conducting visual counts in 2006; therefore, all counts were attributed to summer chum salmon.

Summer chum salmon passage dates were average when compared to the historic run timing, based on 1979–1985 and 1987–2005 runs (Table 2). The summer chum passage quartiles were close to the historic mean dates. The central half of the run passed between July 3 and July 12 (Table 2); and the duration of 9 days is near the historic mean of 10 days. The daily passage between the first and third quartile dates ranged from 16,698 (July 9) to 53,398 (July 7) with an estimated 331,146 fish passing by the sonar site during this time (Table 1). The peak daily passage of 53,398 summer chum occurred on July 7 (Table 1). The summer chum salmon run was composed primarily of age-0.3 and -0.4 fish (98.7%), with age-0.4 chum salmon dominating the samples collected this season (58.7%) (Table 3; Figure 3).

The 2006 pink salmon run was very weak. This was unexpected since pink salmon usually come back to spawn during the even years. The low numbers of returning pink salmon were not deducted from the sonar counts because visual observations indicated the pink salmon return was so weak that their numbers were negligible (Table 1). The 2006 chum salmon escapement estimate of 605,485 was 94% of the mean Anvik River escapement estimate of 643,684 fish, based on 1979–2005 data (Table 2). This year’s escapement fell within the BEG of 400,000 to 800,000 summer chum salmon, and was the highest in the past 9 years.

SPATIAL AND TEMPORAL DISTRIBUTION

There was a distinct diurnal pattern to the passage in 2006 with 41% of the counts recorded between the hours of 2100 and 0500 (Figure 4). Spatially, 85.5% of the chum salmon were detected by the right bank sonar (Figure 5).

AGE AND SEX COMPOSITION

Age and sex composition of the Anvik River chum salmon passing the sonar site changes through the duration of the run. Usually, the trend is an increasing proportion of younger salmon and a higher proportion of female salmon as the run progresses (Fair 1997). From June 30 to July 16, a total of 8 days of sampling was conducted for ASL. The age-0.3 and 0.4 chum salmon accounted for 98.7% of the entire run (Table 3). The age-0.4 chum salmon dominated the entire run accounting for 71.9% of the run at the beginning and dropping down to 51.2% by the end. The age 0.3 chum salmon accounted for 28.1% of the run at the beginning and comprised 47.6% of the run by the end. The age 0.2 chum salmon didn't arrive till the second half of the run and comprised 1.2% of the overall run. There were slightly more females than males throughout the run, except during the second strata when there were a greater number of males; overall 50.7% of the run were females (Table 3).

HYDROLOGIC AND CLIMATOLOGICAL CONDITIONS

The summer of 2006 saw warm temperatures and wet conditions on the Anvik River. Due to rain in the headwaters the water level fluctuated at the sonar site throughout the season (Figure 6). The minimum air temperature was 5°C (July 19) and a maximum high of 28°C (July 5) with an average high and low of 21°C and 9°C (Figure 7). We had trouble with the temperature gauge and were only able to get reading from July 3–12. During this time the water temperature was between 11°C and 15°C.

DIDSON VS SPLIT-BEAM COMPARISON

The DIDSON was operated adjacent to the split-beam on the right bank from June 27 to July 1, July 7 to July 11, and July 13 to July 15 (Figure 8). The relationship between the DIDSON and split-beam counts on June 27 was very different from the rest of the season and since it was the first day of operating both sets of equipment, this data was excluded from the analysis to allow time for fine tuning data collection parameters. With the removal of the data collected on June 27, the DIDSON to split-beam relationship on the right bank was significant ($p < 0.001$) with the resulting equation (Figure 9):

$$DIDSON = \frac{Splitbeam - 159.441}{0.541} \tag{5}$$

The DIDSON was operated adjacent to the split-beam on the left bank from July 3 to July 7 and July 11 to July 12 (Figure 10). The left bank relationship was also significant ($p < 0.001$) and had the following split-beam to DIDSON conversion (Figure 11):

$$DIDSON = \frac{Splitbeam - 8.664}{0.322} \tag{6}$$

The bootstrap analysis resulted in an estimated DIDSON equivalent of 742,482 (SE 32,737) for the right bank and 249,896 (SE 9,690) for the left bank for a total of 992,378 (SE 34,141).

DISCUSSION

ESCAPEMENT ESTIMATION

The 2006 Anvik River summer chum salmon escapement estimate of 605,485 was 6% below the 1979–2005 average escapement of 643,685 and 14% above last year's escapement (525,391) (Table 2). This is the second year since 2002 that the summer chum salmon abundance has been within the BEG. Although the exact reason for the low salmon runs in past years is unknown, scientists speculate poor marine survival results from, or accentuated by, localized weather conditions in the Bering Sea (Kruse 1998).

The 2001 chum salmon year class continued returning to spawn this year as age-0.4. This year's strong run of age 0.4 chum salmon at 356,517 fish is a continuation of the past several years when the 2001 year class came back, as age-0.3 (506,717) fish, and as age-0.2 when 11,691 chum salmon returned. The large number of returning chum salmon from the 2001 year class is encouraging considering the 2001 year class was the 2nd lowest spawning year since 1979 (Table 2).

The 2001 year class has been influencing the historical long-term age for the last couple of years. This year with the large proportion of age 0.4 year olds, the average age of the 2006 run was 4.5 years which is about even with the long-term average of 4.4 years (Figure 12)

In 2005, it was noted that there were no age-0.2 chum salmon returning to spawn (McEwen 2006). This has only happened 5 other times since 1979 (Figure 13) and that the following year the chum salmon returned as 0.3 year olds averaging 50.6% of the entire run. This year, age 0.3 comprised 40.0% of the overall run. The absence of age-0.2 chum salmon doesn't necessarily indicate a poor return of age-0.3 returning to the Anvik River.

SPATIAL AND TEMPORAL DISTRIBUTION

In 2006, chum salmon spatial migration followed historical trends with 84.6% passing on the right bank. Prior to 2006, passage has been associated with the right bank with the exception of 3 years: 1992, 1996, and 1997. In these years only 43%, 45%, and 39% of the adjusted passage occurred on the right bank, respectively (Sandone 1994; Fair 1997; Chapell 2001). The shift to the left bank in those years was attributed to low water conditions that affected chum salmon migration patterns at the sonar site. Although there is no river stage benchmark at the site to allow direct comparison with previous years, subjectively, the water level in 2006 appeared to be higher then the last 4 years.

Buklis (1982) first reported a distinct diurnal salmon migration pattern during the 1981 season with a higher proportion of the migration passing the sonar site during darker hours of the day (Figure 4). Similar diurnal patterns were reported from 1985 through 2005. Temporal distribution of sonar estimates in 2006 indicates a distinct diurnal pattern (Figure 4). The chum salmon could be migrating in greater numbers at night due to the fact that the water is cooler and to escape predation from various birds and mammals.

DIDSON VS SPLIT-BEAM COMPARISON

High water for most of the season prevented normal operation of the split-beam in 2006. Typically, a tower is operated to verify fish detection and refine the aim of the split-beam transducer. The high water made it impossible to visually see fish from the tower. In addition, it was difficult to maintain a functional weir due to persistently high water that affected nearshore detection of targets with the split-beam. The DIDSON was not affected to the same extent because it has a much wider beam width and shorter near field. Due to the unusually high water, we believe the side-by-side comparison in 2006 may not reflect the relationship under normal operating conditions so it will be necessary to repeat the comparison in the future.

Although the side-by-side comparison was not useful for historical comparisons, it was helpful for estimating how many fish may have been missed by the split-beam due to high water. The estimated 992,378 is about 61% higher than the 605,485 estimated with the split-beam. This estimate is likely closer to the true escapement for the Anvik River but there are sources of error that this estimate does not address. For example, since the comparison was done spanning 17 days, it is not certain that the relationship is valid for the entire season, it may have been better or worse at times depending upon water level. One clear result from this comparison is that the transition to the DIDSON will be a positive change for the project and in addition to being easier to operate, it should provide more accurate counts even in high water conditions.

ACKNOWLEDGEMENTS

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TABLES AND FIGURES

Table 1.–Summer chum and pink salmon daily and cumulative counts by bank and total, Anvik River sonar, 2006.

	Daily						Cumulative					
	Right Bank		Left Bank		Daily Total		Right Bank		Left Bank		Daily Total	
Date	Chum	Pink	Chum	Pink	Chum	Pink	Chum	Pink	Chum	Pink	Chum	Pink
6/28	8,242	0	5,580	0	13,822	0	8,242	0	5,580	0	13,822	0
6/29	9,614	0	3,014	0	12,628	0	17,856	0	8,594	0	26,450	0
6/30	25,856	0	8,380	0	34,236	0	43,712	0	16,974	0	60,686	0
7/01	29,075	0	3,953	0	33,028	0	72,787	0	20,927	0	93,714	0
7/02	40,157	0	5,985	0	46,142	0	112,944	0	26,912	0	139,856	0
7/03	28,658	0	6,098	0	34,756	0	141,602	0	33,010	0	174,612	0
7/04	33,693	0	4,566	0	38,259	0	175,295	0	37,576	0	212,870	0
7/05	37,260	0	7,694	0	44,954	0	212,555	0	45,270	0	257,824	0
7/06	46,672	0	5,138	0	51,810	0	259,227	0	50,408	0	309,634	0
7/07	50,210	0	3,188	0	53,398	0	309,437	0	53,596	0	363,032	0
7/08	24,276	0	2,563	0	26,839	0	333,713	0	56,159	0	389,871	0
7/09	14,746	0	1,952	0	16,698	0	348,459	0	58,111	0	406,569	0
7/10	19,202	0	2,110	0	21,312	0	367,660	0	60,221	0	427,881	0
7/11	21,062	0	3,228	0	24,289	0	388,722	0	63,448	0	452,170	0
7/12	16,460	0	2,372	0	18,832	0	405,182	0	65,820	0	471,002	0
7/13	12,654	0	2,189	0	14,843	0	417,836	0	68,009	0	485,846	0
7/14	8,446	0	1,310	0	9,756	0	426,282	0	69,319	0	495,602	0
7/15	13,619	0	2,804	0	16,423	0	439,901	0	72,123	0	512,025	0
7/16	6,904	0	2,139	0	9,043	0	446,805	0	74,262	0	521,067	0
7/17	1,940	0	1,647	0	3,587	0	448,745	0	75,909	0	524,654	0
7/18	10,306	0	2,476	0	12,782	0	459,051	0	78,384	0	537,435	0
7/19	11,308	0	2,947	0	14,255	0	470,359	0	81,331	0	551,690	0
7/20	15,645	0	4,731	0	20,376	0	486,005	0	86,062	0	572,066	0
7/21	9,546	0	1,894	0	11,440	0	495,551	0	87,956	0	583,507	0
7/22	5,238	0	1,374	0	6,612	0	500,789	0	89,330	0	590,119	0
7/23	3,473	0	1,290	0	4,763	0	504,261	0	90,620	0	594,881	0
7/24	2,958	0	922	0	3,880	0	507,219	0	91,542	0	598,761	0
7/25	2,120	0	660	0	2,780	0	509,339	0	92,202	0	601,541	0
7/26	3,180	0	764	0	3,944	0	512,519	0	92,966	0	605,485	0

Note: The large box indicates the central 50% of the run (second and third quartiles). The small box indicates the median passage date (mean quartile).

Table 2.–Annual passage estimates and associated passage timing statistics for summer chum salmon runs, Anvik River sonar, 1979–2006.

Year	Sonar passage estimate	Day of first Salmon Count	First Quartile day	Median day	Third Quartile day	Days Between Quartiles: First count & first quartile	First & median	Median & third	First & third
1979	277,712	6/23	7/02	7/08	7/12	9	6	4	10
1980	482,181	6/28	7/06	7/11	7/16	8	5	5	10
1981	1,479,582	6/20	6/27	7/02	7/07	7	5	5	10
1982	444,581	6/25	7/07	7/11	7/14	12	4	3	7
1983	362,912	6/21	6/30	7/07	7/12	9	7	5	12
1984	891,028	6/22	7/05	7/09	7/13	13	4	4	8
1985	1,080,243	7/05	7/10	7/13	7/16	5	3	3	6
1986	1,085,750	6/21	6/29	7/02	7/06	8	3	4	7
1987	455,876	6/21	7/05	7/12	7/16	14	7	4	11
1988	1,125,449	6/21	6/30	7/03	7/09	9	3	6	9
1989	636,906	6/20	7/01	7/07	7/13	11	6	6	12
1990	403,627	6/22	7/02	7/07	7/15	10	5	8	13
1991	847,772	6/21	7/01	7/10	7/16	10	9	6	15
1992	775,626	6/29	7/05	7/08	7/12	6	3	4	7
1993	517,409	6/19	7/05	7/12	7/18	16	7	6	13
1994	1,124,689	6/19	7/01	7/07	7/11	12	6	4	10
1995	1,339,418	6/19	7/01	7/06	7/11	12	5	5	10
1996	933,240	6/18	6/25	7/01	7/06	7	6	5	11
1997	605,752	6/19	6/28	7/03	7/10	9	5	7	12
1998	487,301	6/22	7/05	7/10	7/14	13	5	4	9
1999	437,356	6/27	7/06	7/10	7/16	9	4	6	10
2000	196,349	6/21	7/08	7/11	7/13	17	3	2	5
2001	224,058	6/26	7/06	7/10	7/15	10	4	5	9
2002	459,058	6/22	7/03	7/07	7/12	11	4	5	9
2003	256,920	6/21	7/05	7/10	7/15	14	5	5	10
2004	365,353	6/22	6/29	7/05	7/09	7	6	4	10
2005	525,391	6/26	7/04	7/10	7/15	8	6	5	11
2006	605,485	6/28	7/03	7/06	7/12	5	3	6	9
Average	**643,684**	**6/22**	**7/02**	**7/08**	**7/12**	**10**	**5**	**5**	**10**
Median	**502,355**	**6/21**	**7/03**	**7/08**	**7/13**	**10**	**5**	**5**	**10**
SD	**354,857**		**3.6**	**3.2**	**3.0**	**3**	**1**	**1**	**2**

Note: The mean and standard deviation of the timing statistics includes estimates from years 1979–1985 and 1987–2003. In 1986, sonar counting operations were terminated early, probably resulting in the incorrect calculation of the quartile statistics. Therefore, the 1986 run timing statistics were excluded from the calculation of the overall mean and timing statistic and associated standard deviation (SD).

Table 3.–Age and sex composition of chum salmon, Anvik River sonar, 2006.

			Age											
			(0.2)			**(0.3)**			**(0.4)**			**Total**		
2006 Sample Date (Strata)	**Sample Size**		**Esc. Estimate**	**Sample count**	**%**	**Esc. Estimate**	**Sample count**	**%**	**Esc. Estimate**	**Sample count**	**%**	**Esc. Estimate**	**Sample count**	**%**
6/30, 7/2	146	Males	0	0	0.0	19,136	16	11.0	68,170	57	39.0	87,306	73	50.0
(6/28–7/3)		Females	0	0	0.0	29,899	25	17.1	57,407	48	32.9	87,306	73	50.0
		Subtotal	0	0	0.0	49,035	41	28.1	125,577	105	71.9	174,612	146	100.0
7/4	78	Males	0	0	0.0	24,235	14	17.9	60,587	35	44.9	84,822	49	62.8
(7/4–6)		Females	0	0	0.0	31,159	18	23.1	19,042	11	14.1	50,201	29	37.2
		Subtotal	0	0	0.0	55,394	32	41.0	79,629	46	59.0	135,023	78	100.0
7/7, 9	94	Males	3,033	2	2.1	25,778	17	18.1	31,843	21	22.4	60,655	40	42.6
(7/7–11)		Females	3,033	2	2.1	37,908	25	26.6	40,941	27	28.7	81,881	54	57.4
		Subtotal	6,066	4	4.3	63,686	42	44.7	72,784	48	51.1	142,536	94	100.0
7/12–13, 16	164	Males	935	1	0.6	26,176	28	17.1	38,329	41	25.0	65,440	70	42.7
(7/12–26)		Females	935	1	0.6	46,742	50	30.5	40,198	43	26.2	87,875	94	57.3
		Subtotal	1,870	2	1.2	72,918	78	47.6	78,527	84	51.2	153,315	164	100.0
Season Total	482	Males	3,968	3	0.6	95,325	75	15.5	198,929	154	31.9	298,223	232	49.3
		Females	3,968	3	0.6	145,707	118	24.5	157,588	129	26.8	307,263	250	50.7
		Total	7,937	6	1.2	241,032	193	40.0	356,517	283	58.7	605,486	482	100.0

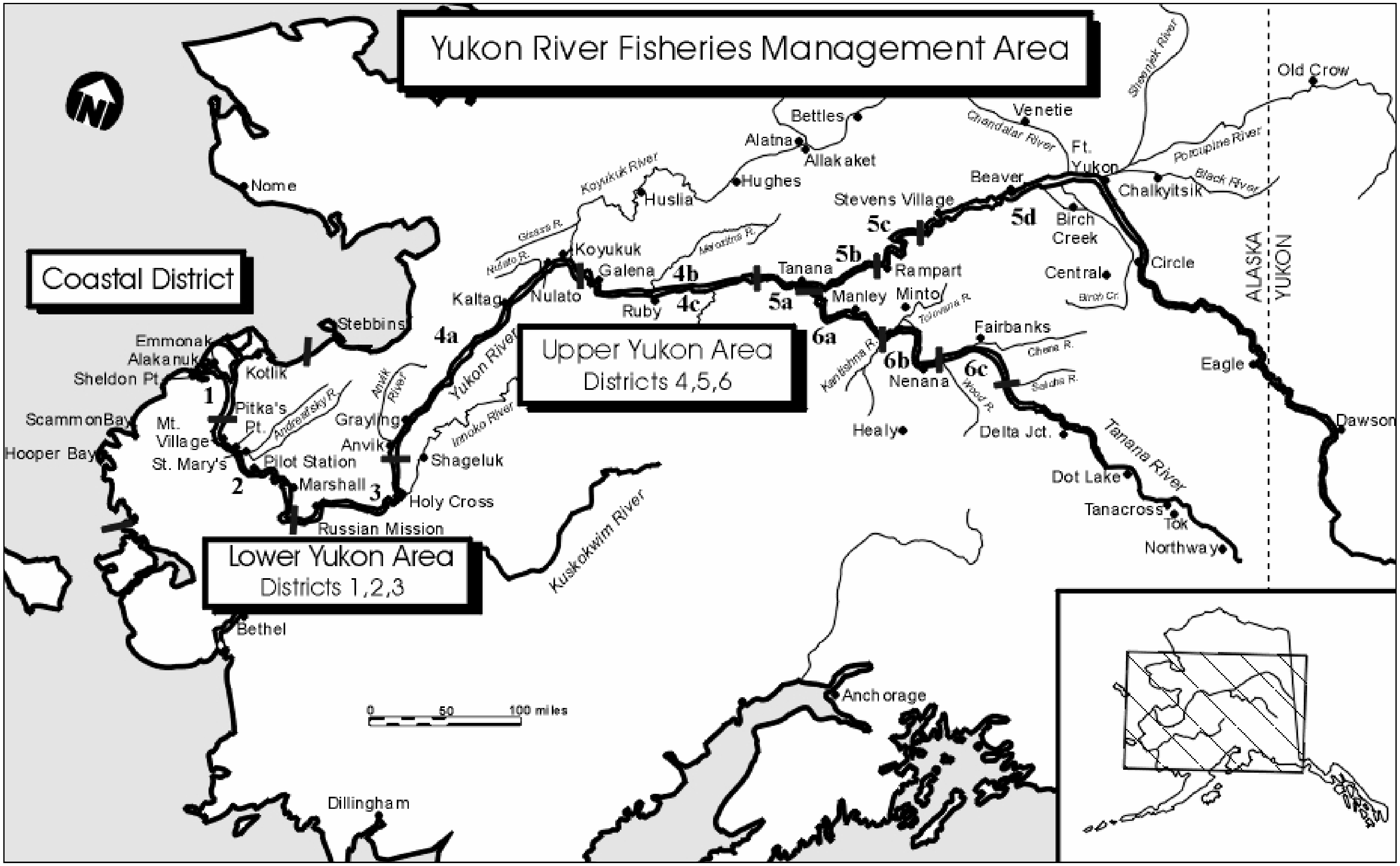


Figure 1.–Alaska portion of the Yukon River drainage showing communities and fishing districts.

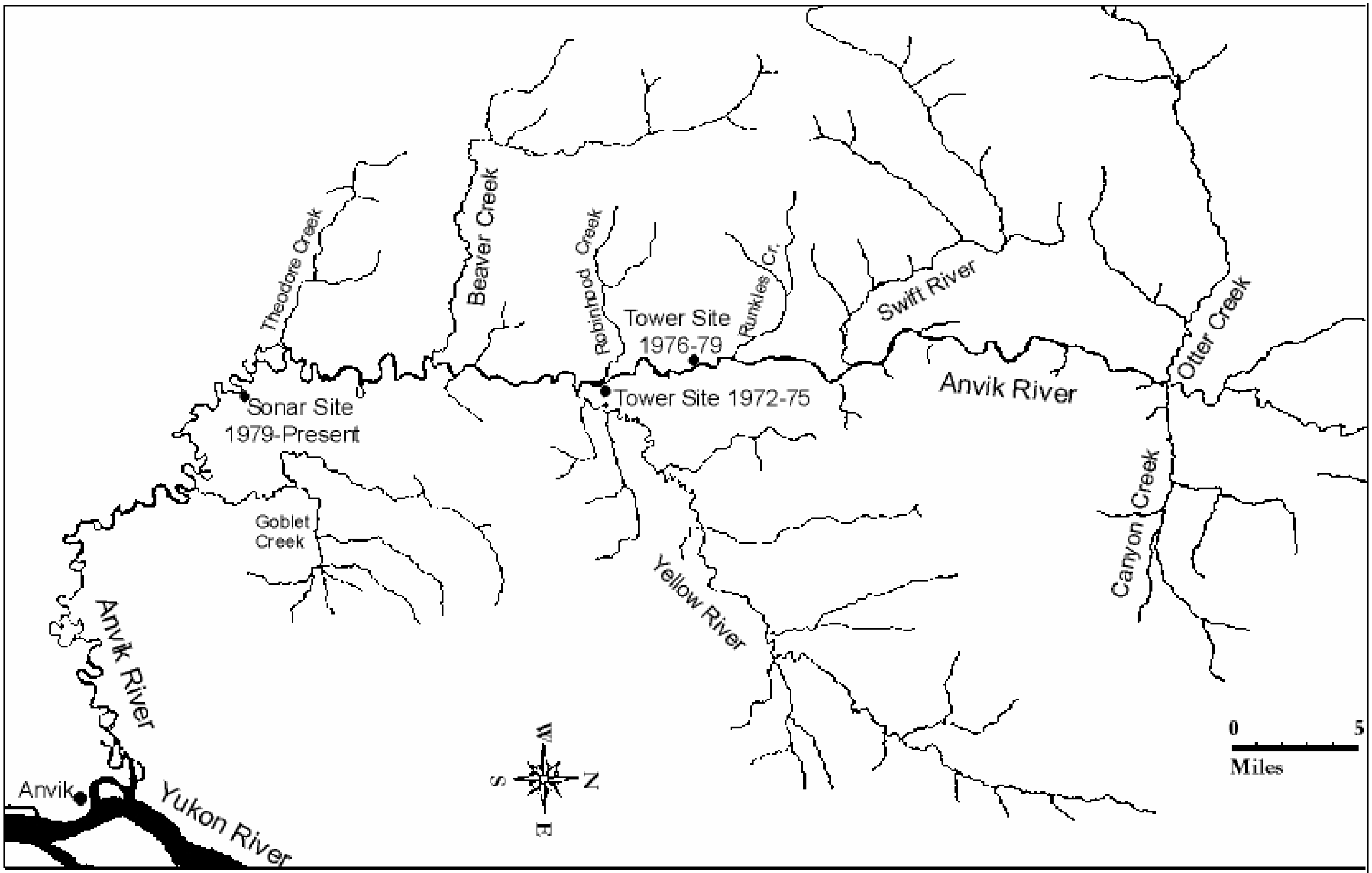


Figure 2.–Anvik River drainage with historical chum salmon escapement project locations.

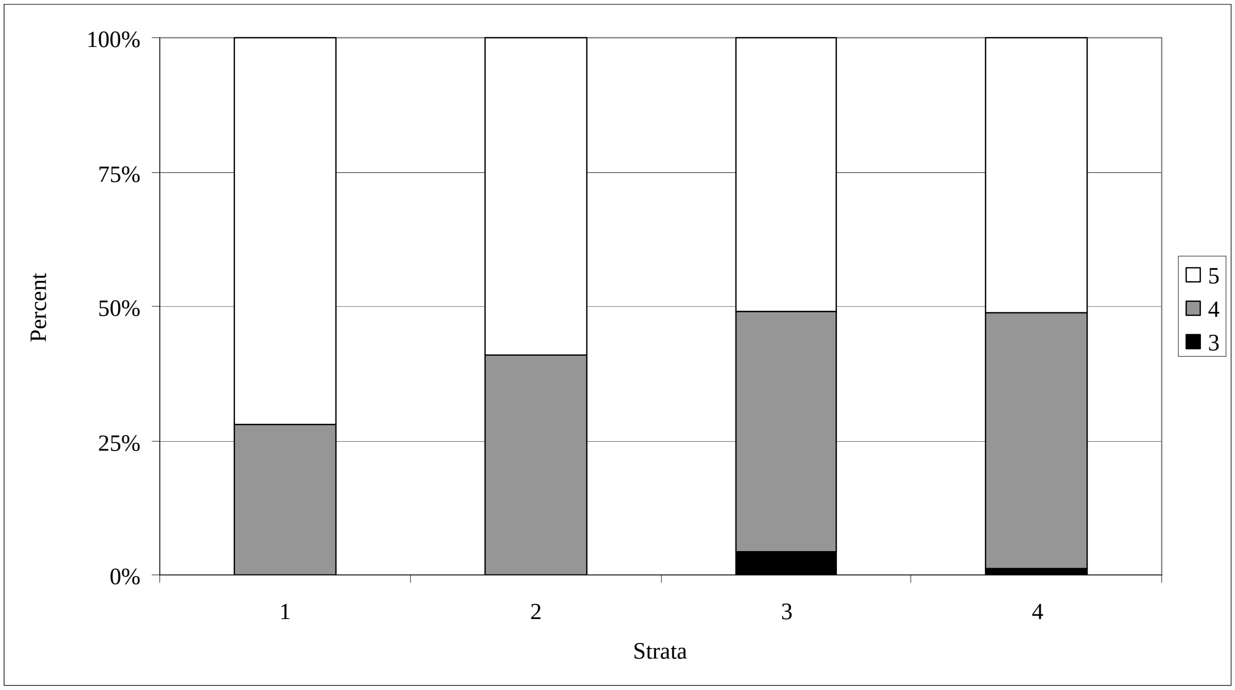


Figure 3.–Chum salmon age composition, Anvik River sonar, 2006.

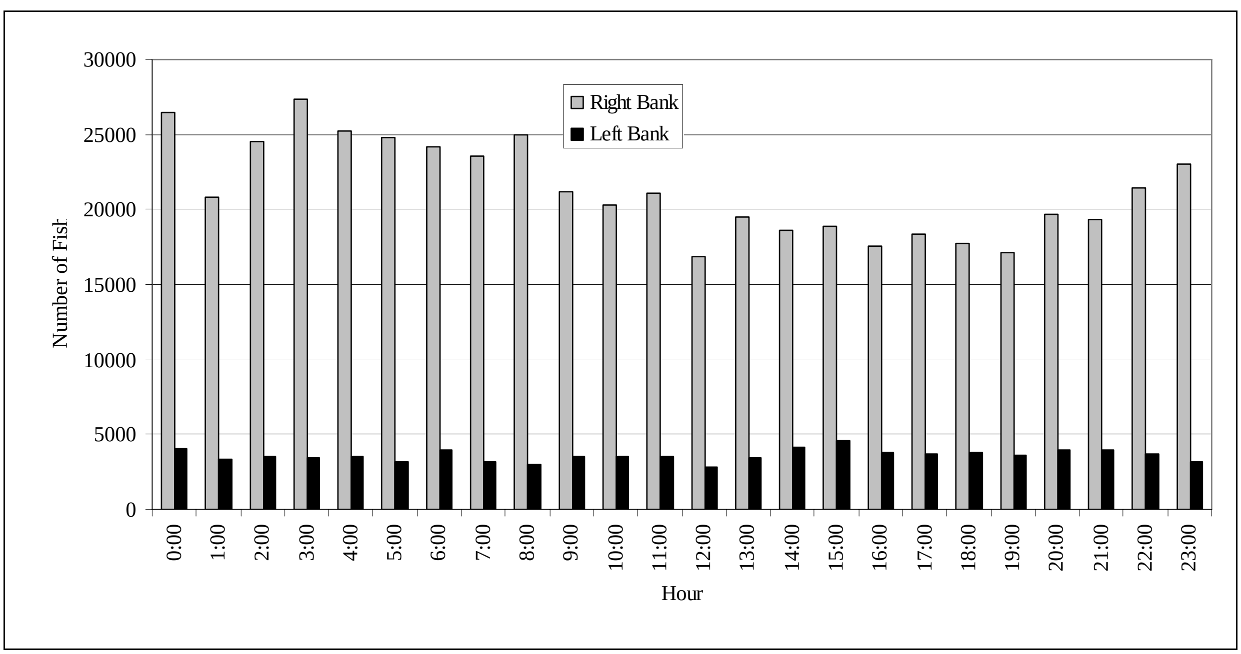


Figure 4.–Estimated passage of chum salmon by hour for each bank, Anvik River sonar, 2006.

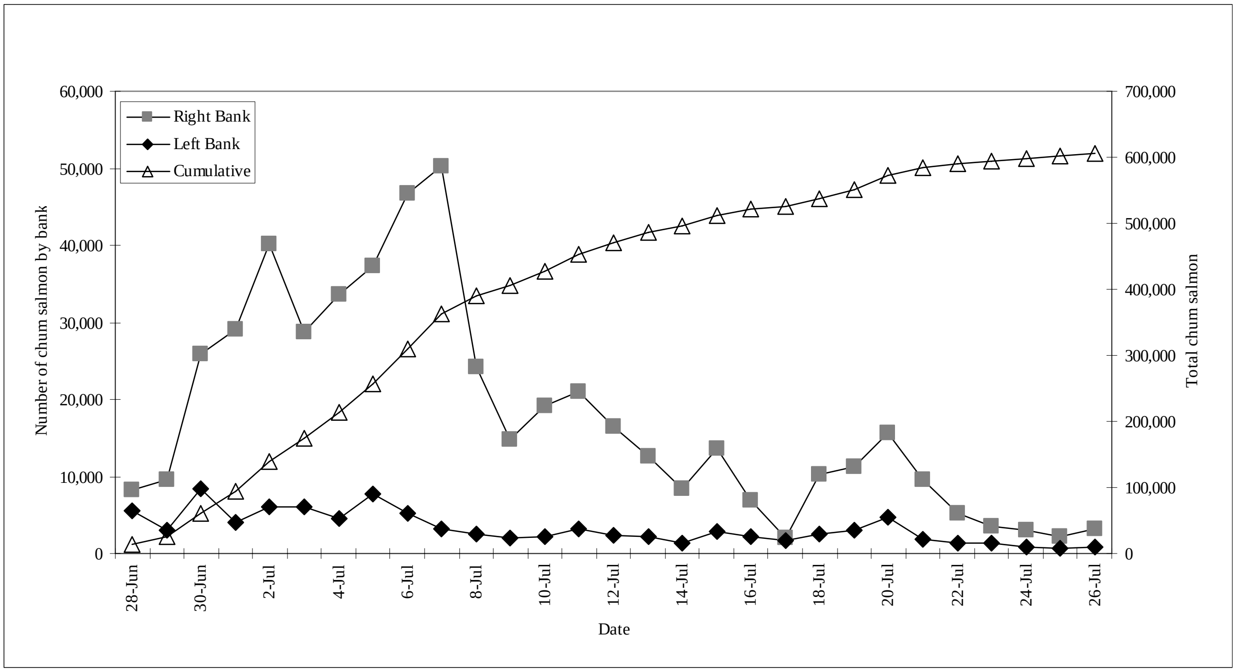


Figure 5.–Chum salmon daily and cumulative counts, Anvik River sonar, 2006.

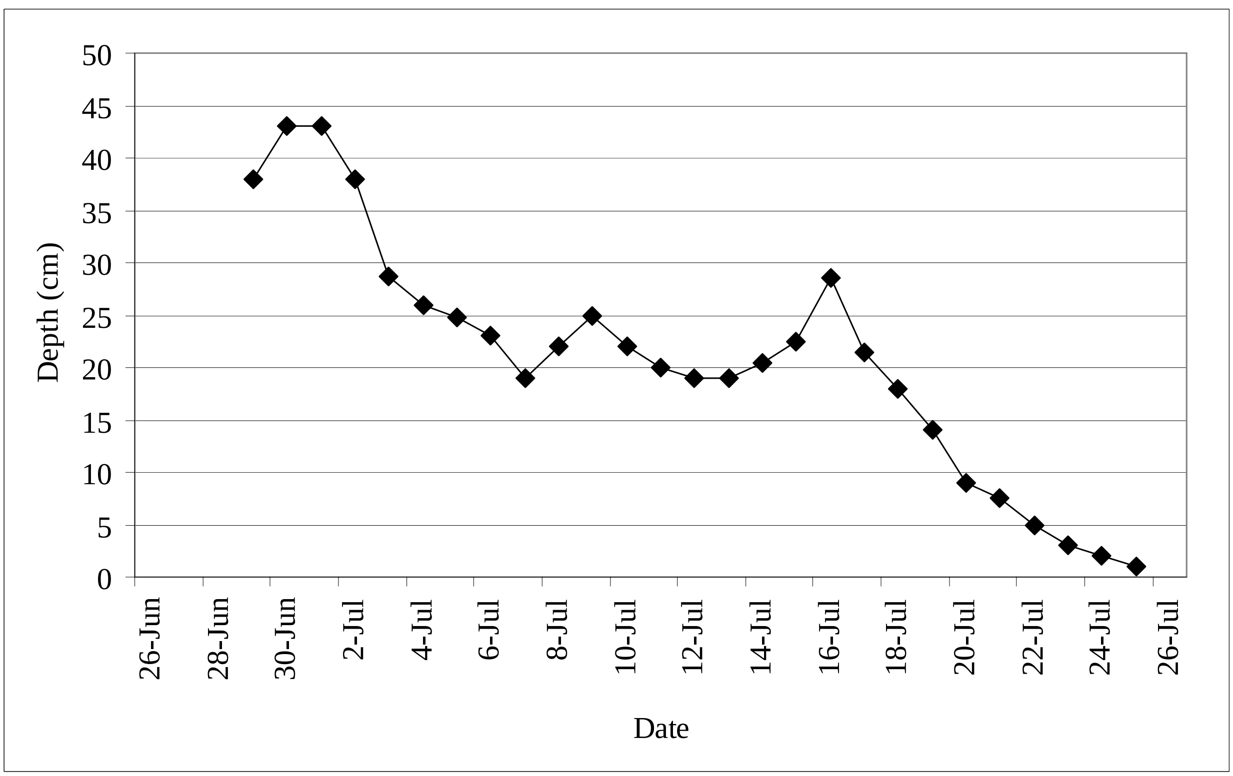


Figure 6.–Water depth at Anvik River sonar, 2006.

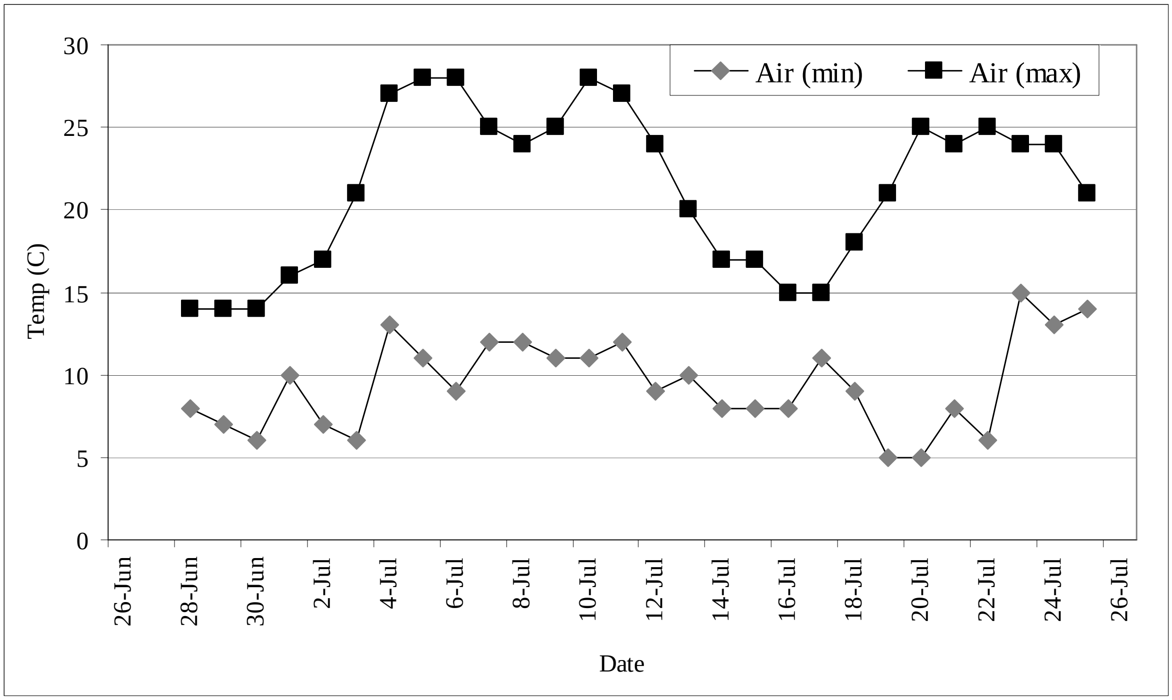


Figure 7.–Hydrological and climatological observations, Anvik River sonar, 2006.

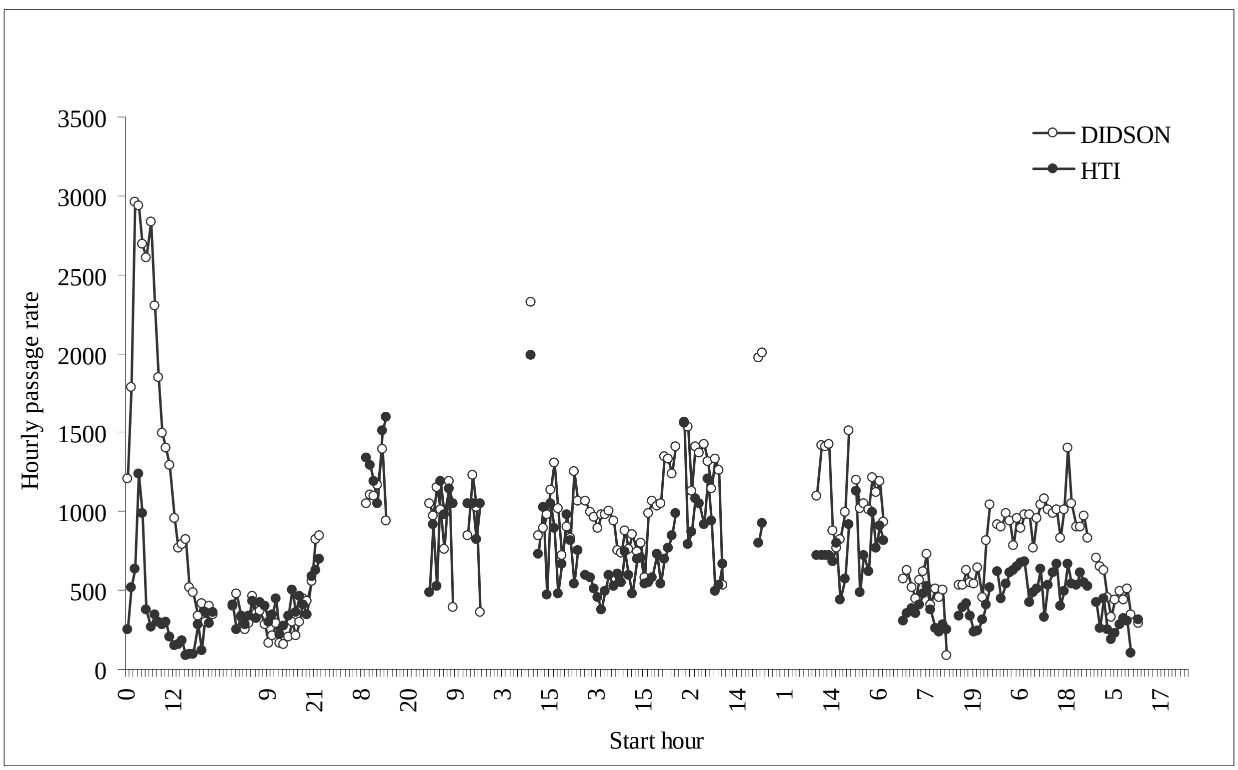


Figure 8.–Right bank hourly DIDSON and split-beam paired counts, Anvik River sonar, 2006.

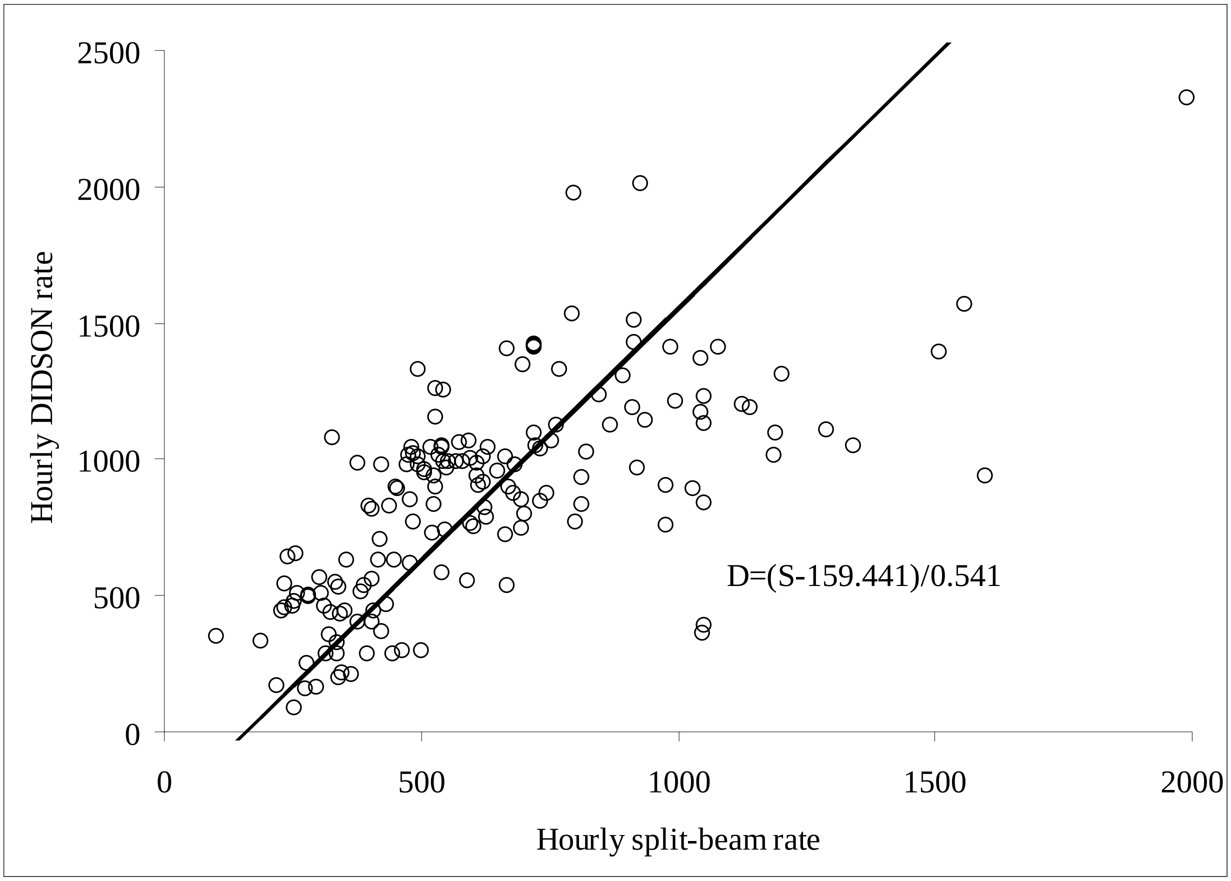


Figure 9.–Right bank DIDSON versus split-beam scatter plot with regression line.

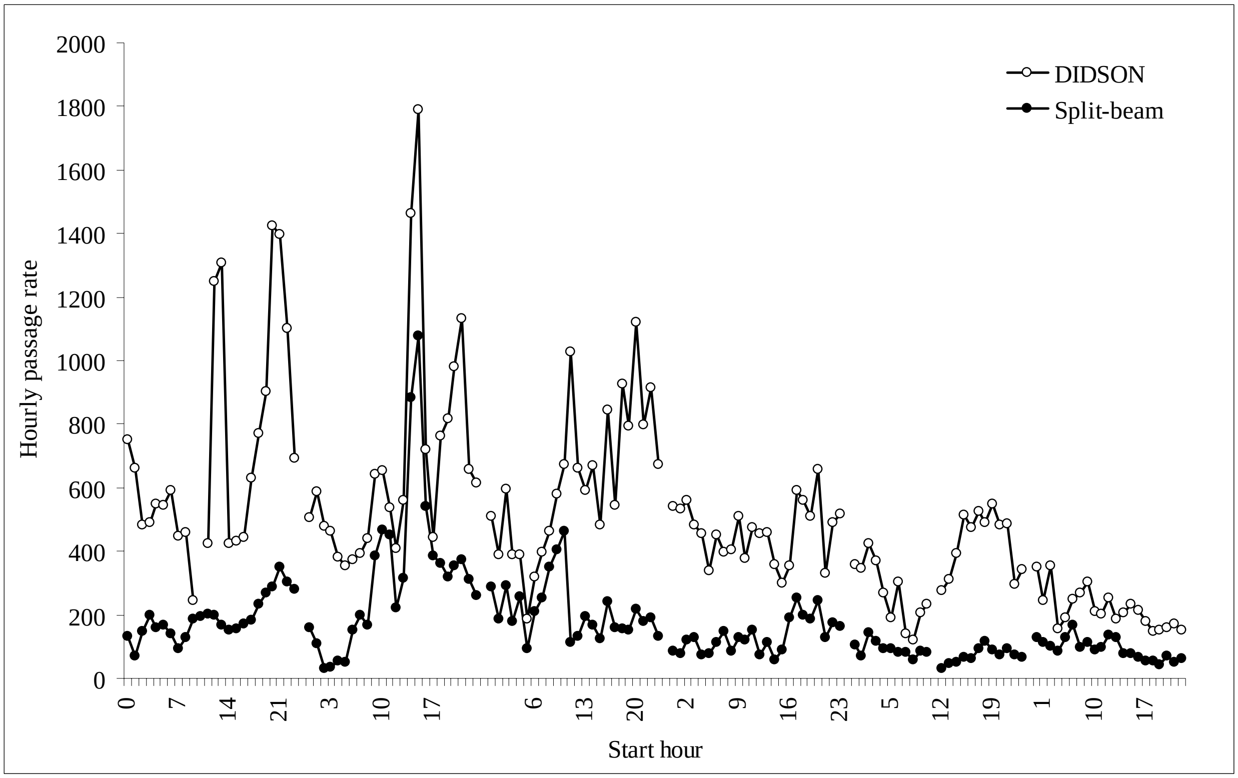


Figure 10.–Left bank hourly DIDSON and split-beam paired counts, Anvik River sonar, 2006.

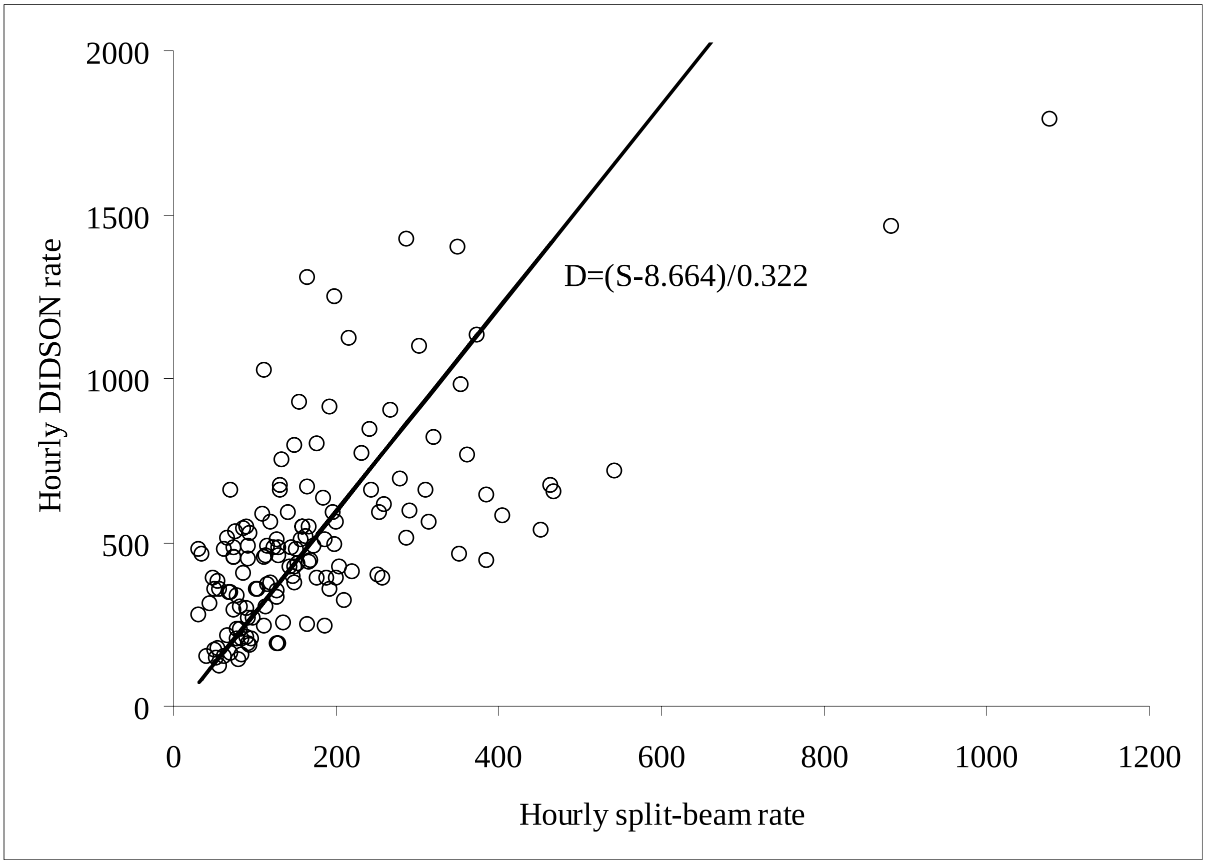
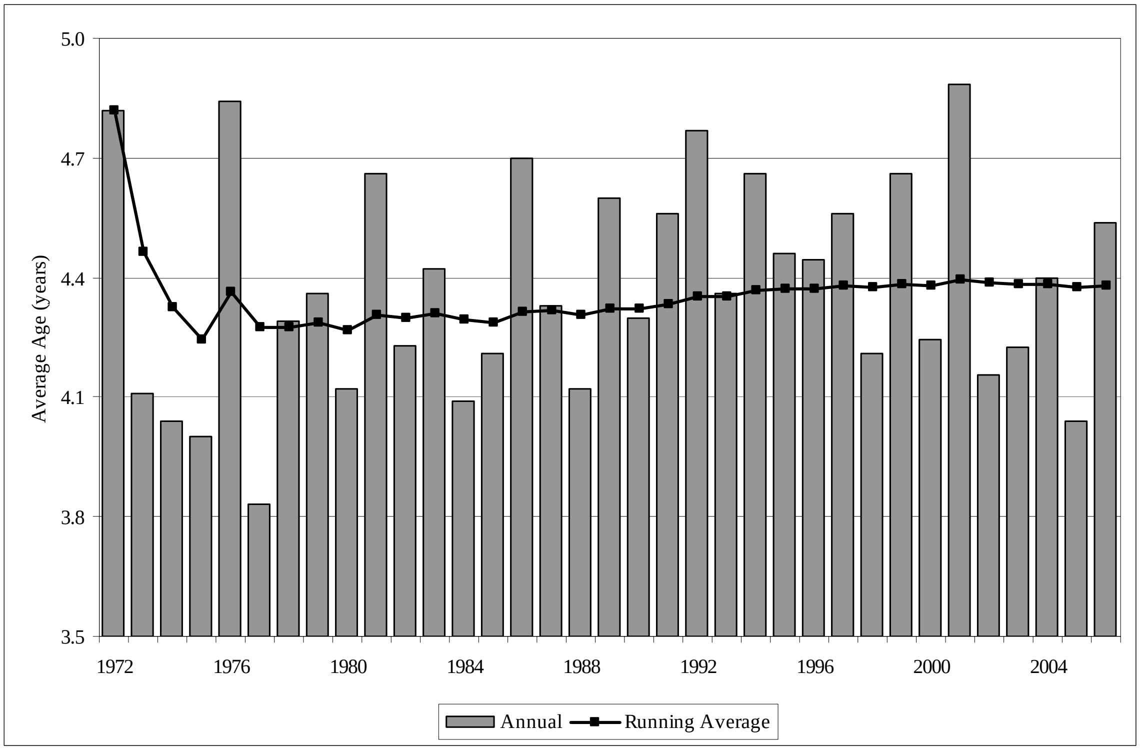


Figure 11.–Left bank DIDSON versus split-beam scatter plot with regression line.



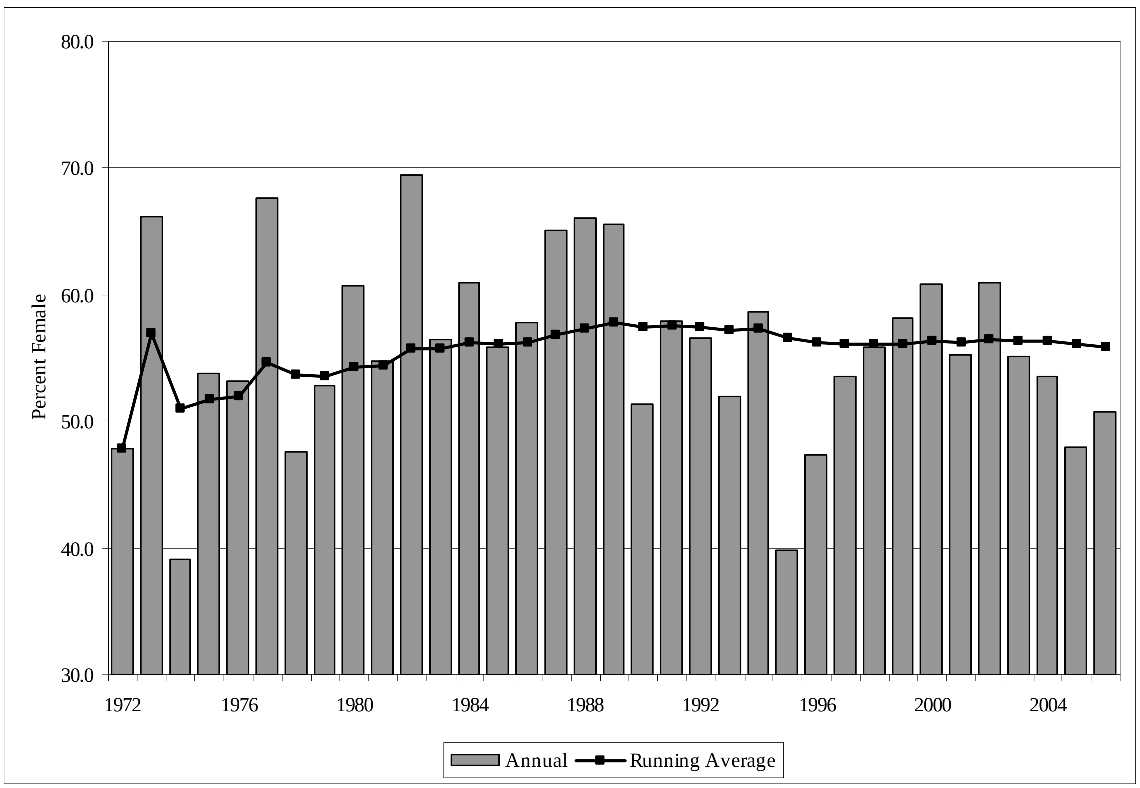


Figure 12.–Annual age at maturity (top) and percentage of females (bottom) of the Anvik River chum salmon escapement, 1972–2006.

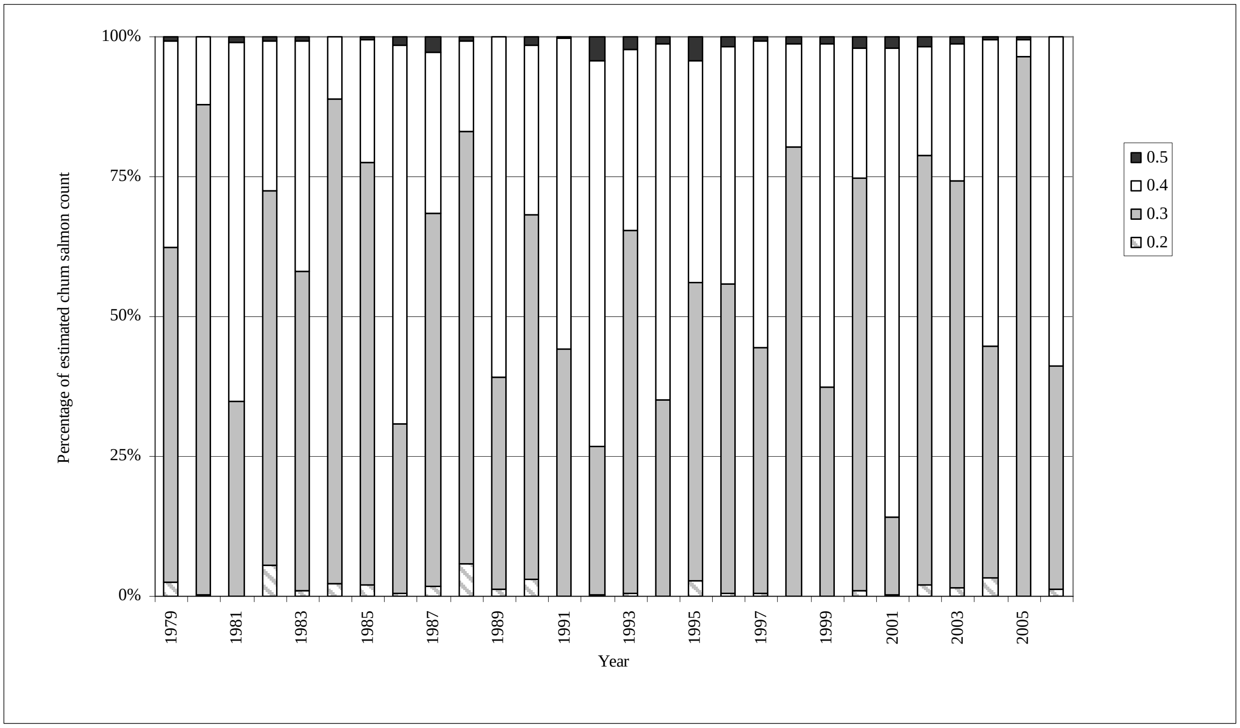


Figure 13.–Percentage of chum salmon by age since 1979, Anvik River sonar.

APPENDIX A.

Appendix A1.–Technical specifications for the HTI Model 241 Portable Split-Beam Digital Echo Sounder.

Size:	10 inches wide x 4.3 high x 17 long, without PC or transducer (254 mm wide x 109 high x 432 long).
Weight:	20 lb. (9 kg) without PC or transducer.
Power Supply:	Nominal 12 VDC standard (120 VAC and 240 VAC optional).
Operating Temperature:	5-50°C (41-122°F).
Power Consumption:	30 watts (120 - 200 kHz), without laptop PC.
Frequency:	200 kHz standard (120 kHz and 420 kHz optional).
Transmit Power:	100 watts standard for 120-200 kHz. 50 watts standard for 420 kHz.
Dynamic Range:	140 dB
Transmitter:	Output power is adjustable in four steps over a 20 dBw range (+2, +8, +14, and 20 dBw).
Pulse Length:	Selectable from 0.1 ms to 1.0 ms in 0.1 ms steps.
Bandwidth:	Receiver bandwidth is automatically adjusted to optimize performance for the selected pulse length.
Receiver Gain:	Overall receiver gain is adjustable in five steps over a 40 dB range (-16, -8, 0, +8, +16 dB).
TVG Functions:	Simultaneous 20 and 40 log(R)+2αr TVG. Spreading loss and alpha are programmable to nearest 0.1 dB. Total TVG range is 80 dB. TVG start is selectable in 1m increments. The minimum TVG start is 1.0 m to maximum of 200 m
Receiver Blanking:	Start and stop range blanking is selectable in 1m steps.
Undetected Output:	12 kHz, for each formed beam
Detected Output:	10 volts peak
System Synchronization:	Internal or external trigger
Ping Rate:	0.5-40.0 pings/sec
Phase Calculation:	Quadrature demodulation
Angular Resolution:	+/- <0.1° (6° beam width, 200 kHz)
Tape recording:	With Split-Beam Data Tape Interface and optional Digital Audio Tape (DAT) recorder, directly records the digitized split-beam data, permitting complete reconstruction of the raw data output.
Calibrator:	source. Pulse and CW calibration functions provided in step settings.
Positioning:	GPS positioning information (NMEA 0183 format) via serial port of computer

Source: Model 241 operator’s manual.